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Effect of Social Distancing on COVID-19 Infection Using a Multi-Agent Simulation

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Abstract

As everyone knows, COVID-19 has spread all over the world, and cumulative infected number is still increasing day by day. Therefore, interventions to limit the spread of COVID-19 should be considered for each event. Effective interventions to minimize COVID-19 transmission vary for each event, according to a quantitative framework called event R. Of those events, the example of school is the most likely to be infected, but the intervention of distancing cut the number of new infections in half.

Therefore, we use a multi-agent simulation to simulate COVID-19 transmission with no measures and with social distancing. In order to simulate under the same conditions as in the event R calculation, our simulation is performed under the following conditions: a single infected person enters the classroom with the first multiple uninfected people and a certain time passes. After that, the person enters the classroom with the same number of new uninfected people, and the process is repeated 8 times.

The simulation results show that there is a relationship between social distancing and the spread of infection, but the rate of decrease is not constant.

1. Introduction

The interventions to limit the spread of COVID-19 should be considered for each event such as public transport, birthday parties, and high schools because the spread has not yet converged around the world. Here, there is a quantitative framework to determine which interventions are likely to have the most effect in which events. The concept of " event R " is the expected number of new infected people due to the presence of a single infected person at an event[1].

Figure 1 adapted from Paul Tuppera, Himani Bouryb, Madi Yerlanova, and Caroline Colijn shows three types of interventions for reducing event R. They are measures to reduce transmission such as face masks, barriers, and hand hygiene, social distancing, and social bubbles.

Then, in workplaces and businesses, it is necessary to determine whether their settings are linear or saturating, and whether people are strongly mixed or bubbling. Figure 2 also adapted from Paul Tuppera, Himani Bouryb, Madi Yerlanova, and Caroline Colijn shows the values of event R for no measures and each intervention. In Fig. 2, the setting of high schools is saturating and mixing, and the results show that different events have different effective interventions.

The high schools that is most likely to be susceptible to infection in these four settings are focused on. Then, event R is halved by halving number of contacts in event R considering the social distancing. In addition, the calculations are made under the following conditions in high schools: a single infected person contacts the first multiple uninfected people for a certain time. After that, the same number of new uninfected people are contacted. This is repeated 8 times, making the total time one week.

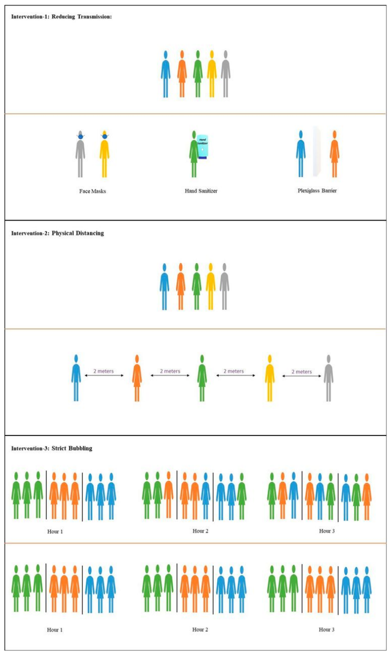

Figure 1: The three types of intervention

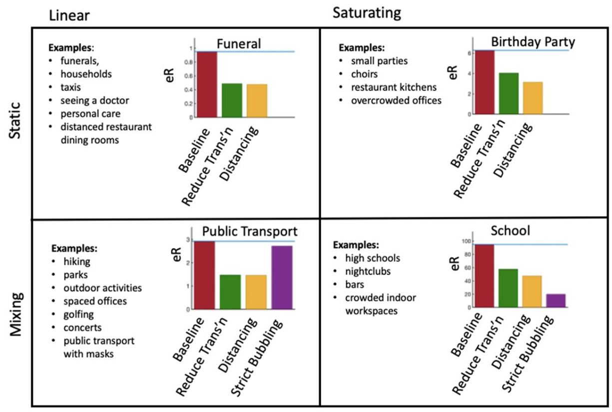

Figure 2: Four different kinds of events. They are (Left) linear (low transmission probability), (Right) saturating (high transmission probability), (Upper) static (same contacts for whole event), and (Lower) Mixing (high turnover of contacts)

Therefore, we use a multi-agent simulation to simulate the number of COVID-19 infections in a high school without measures and with social distancing. Then, Examine whether the number of new infections is reduced by half by practicing social distancing, as in the event R calculation. In addition, examine the effect of infection reduction on changes in the proportion of people practicing social distancing.

2. Multi-Agent Simulation

The multi-agent simulation (Hereinafter referred to as MAS) is based on the idea that programs do exhibit behaviors entirely described by the program instructions. It is possible to simulate an artificial world inhabited by interacting processes, by relating an individual to a program. We can simulate by transposing the population of a real bio system to its artificial counterpart in which particular hypotheses can be explored by repeating experiments. Each organism of the population is represented as an agent whose behavior is programmed with all the required details[2].

The simulation of the number of people infected with infectious diseases is sometimes performed using a mathematical model based on differential equations. In addition, overall parameters such as infection rate and mortality rate are defined, in the simulation using a mathematical model. However, in the simulation using a MAS, it is possible to consider more details than in the simulation using a mathematical model because several parameters are given to each agent.

3. Model

Our one-week simulation using a MAS of the number of new infections uses the SIR model. The SIR model is a model in which agents are given the states S (susceptible), I (infectious), and Re (recovered), and their states change in turn. The SIR model is also applied to the early spread of SARS-CoV-2 and fits the reported COVID-19 cases in Italy.

In this study, Our simulation using a MAS is performed for the case with no measures and social distancing. Recovery and death are not considered in this one-week simulation because the infectious period is approximately 8 days[3].

4. Simulation and Conditions

Our simulation is performed with no measures and with practicing social distancing. The conditions of the simulation are shown below.

- The simulation is repeated 8 times with one initially infected person, 20 uninfected people, and a 400 square meter (20m $\times$ 20m) classroom.
- The agent's initial position and direction of movement are determined randomly.
- All of the agents are between the ages of 15 and 18, and all of the infections are infectious and asymptomatic, and there is no quarantine of the infections.
- The initial infected person is in the same classroom as a total of 160 uninfected people, and is in a situation where he or she can contact those uninfected people because the initial infected person is always infectious for one week.
- If an infection enters within a radius of 1m around an uninfected person, the uninfected person becomes infected, and the time required for virus transmission is 15 minutes. This is based on the definition of intensive contact in Japan.
- For all agents, behavior and contact outside the classroom is not considered.
- In order to obtain results under the same conditions as the event R calculation, the time of our 8 repeated simulations is set to one week. Weekends are not taken into account, and the time for one simulation is set at 8 hours.

In the simulation of social distance, a repulsion force that is inversely proportional to the distance between the agents should be applied if another agent enters within a radius of 2m around an agent. The repulsion force effects the speed and direction of movement of the agents, and the agents always try to keep their distance from each other.

In this study, the proportion of the number of new infections to the 20 uninfected people is obtained. The data obtained from 8 repeated simulations are averaged, and this simulation is performed 10 times. Then, the average of the data from these 10 times is obtained. In addition, our simulations are performed with no measures and with the number of agents practicing social distancing set to 10 different values, from 10 to 100% of the number of uninfected people. However, in the simulation with social distancing, one initially infected person practices social distancing in all situations. For example, the total number of agents practicing social distancing is 11 if 50% of the agents practice social distancing.

5. Results

An image of the result of one of our 8 repeated simulations (with no measures) is shown in Fig. 3. The scatter plot above shows the agents, and the movement of the agents and the infection situation can be recognized as a video by outputting 32 images continuously. The red points are the infected agents and the blue points are the uninfected agents. The graph below shows the number of infected and uninfected people at the same time as the scatter plot above. In this graph, the horizontal axis is time and the vertical axis is the number of infected people, and the red area rises as the number of infected people increases. In the case of the simulation shown in Fig. 3, one initially infected person eventually generates 14 new infections.

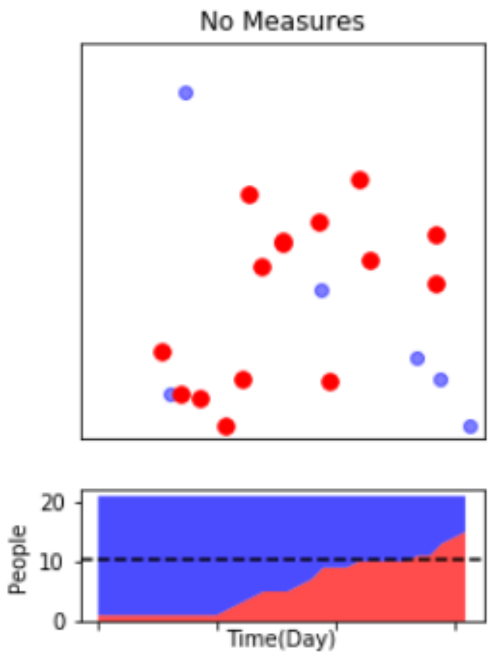

Figure 3: An image of the result of one of our 8 repeated simulations (with no measures)

The results obtained from 11 different simulations are shown in Fig. 4. The value of 0% for the proportion of people practicing social distancing is the result of the simulation with no measures.

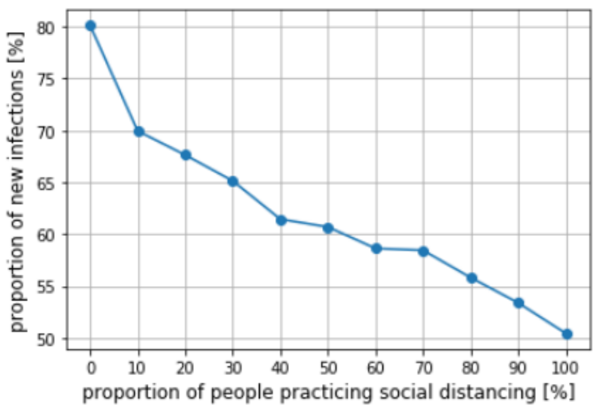

Figure 4: Results of simulations that performed with no measures and with the number of agents practicing social distancing set to 10 different values, from 10 to 100% of the number of uninfected people

In Fig. 4, the number of new infections decreased as the proportion of people practicing social distancing is increased. However, the number of new infections is not reduced by half compared to the simulation with no measures as in the event R calculation. The social distancing is represented by halving the number of people in contact in the event R calculation, whereas the agents in a MAS move randomly and always try to keep a distance of 2m each other. Even if the contacts between initially infected person and uninfected people is halved in a MAS, the new infections contact each other in one simulation. Therefore, the number of new infections decreases by only about 30% when people practice social distancing of 2m because of secondary infections in the simulation using a MAS.

In addition, the simulation results for the case with no measures and the case with 10% of the people practicing social distancing show that there is a difference of about 10% between these two values. The value of this difference is larger than the difference of the other values. Then, one initially infected person practices social distancing in all simulations with social distancing. Therefore, this confirms that the effect of practicing social distancing on the spread of infection by infectious people is significant.

6. Conclusions

The purpose of this study was twofold. To confirm whether the number of new COVID-19 infections with social distancing is reduced by half compared with no measures. To analyze the effect of the number of people practicing social distance on the spread of infection.

Then, our simulations were performed using a MAS, with no measures and with the number of agents practicing social distancing set to 10 different values ranging from 0 to 100% of the number of agents.

As a result, in the simulation with social distancing, the number of new infections is not reduced by half compared to the simulation with no measures. However, the number of new infections decrease as the proportion of people practicing social distancing is increased.

References

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